ANALYZING THE DIFFERENCE BETWEEN BIKE SHARE TRIPS MADE ON REGULAR AND ELECTRIC BICYCLES

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ANALYZING THE DIFFERENCE BETWEEN BIKE SHARE TRIPS MADE ON REGULAR AND ELECTRIC BICYCLES

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LIST OF SYMBOLS AND ABBREVIATIONS

CBD	Central Business District
e-bike	Electrically Assisted Bicycle

SUMMARY

In 2017, JUMP Bicycle Company introduced dockless electric bicycles in several cities in the United States. Two of these cities were Austin, TX, and Atlanta, GA, both of which already had bikeshare companies operating with traditional non-electric bicycle fleets. This makeup of two unique sources of data for non-electric and electric bikeshare in these two cities presents a unique opportunity to study the difference between trips made on a pedal-assist bicycle and a standard bicycle that are a part of an urban bikeshare network. To conduct this work, the researchers collected three months of data in each of the cities and analyzed the data by comparing trip counts, mapping the origins and destinations and the routes of the trips, and finally analyzing the distance and other characteristics of the trips. The results of the study found an increase in the number of bikeshare trips taken in both cities, however, many of these new electric bicycle trips come at the expense of existing bikeshare trips. The geographic area covered by the trips increase greatly when electric bicycles trips are compared to regular bike trips in both cities, however, the average trip lengths stayed constant. Results suggest the introduction of electric bikeshares is a promising prospect to increase mobility and will need to be incorporated into transportation plans for cities moving forward.

CHAPTER 1. INTRODUCTION

The impact that electric bicycles (e-bikes) will have on transportation mobility is receiving increased attention over time. In general, it has been found that e-bikes can mitigate many of the most common barriers to bicycle commuting such as increased physical demand, topographic challenges, and time pressures (2,9,11,15, 21). However, it is true that many of the potential and perceived impacts e-bikes will have on transportation mobility are still poorly understood. In particular, research in situations where e-bikes are present in cities has been limited, and where research has been undertaken, it is typically on a trial basis or at a very small scale. The methodology of this research presents an opportunity to observe the impact of e-bikes operating in a non-structured environment. In this way, we can begin to understand what these impacts are and how they may change mobility options in our cities.

In September of 2017, JUMP first introduced electric bikes in Washington D.C. By the end of 2018, they had expanded to an additional 13 cities. The introduction of electric bikes into the bike-share sphere presents a unique opportunity to investigate the impact electric bikes are having in the cities where they have been introduced. The focus of this research is to identify and analyze the difference in the performance, operation, and character of trips made on a pedal-assist bicycle and a standard bicycle that are part of an urban bike share network in major cities. In this paper, the researchers seek to answer the following three questions:

1. Does real-world evidence suggest e-bikes mitigate the barriers to bicycling as the literature would suggest (3)(7) (27)?
2. What is the difference in the geographic nature of e-bikes vs. non-e-bike trips operating as a part of an urban bikeshare network?
3. Are e-bikes generating new bike trips?

The hypothesis is that data will show increased bicycle trip lengths and more trips between residential areas and businesses/workplace areas, indicating that the bikes are serving as an alternative to other transportation modes. The researchers hope to demonstrate that e-bikes prove to be a significant mode of transportation and provide a commute option in a way that standard bike shares do not. If this is viable moving forward, municipalities will take greater notice of the technology and work to better incorporate the bikes into the transportation plans, so that eventually, they become a well-integrated part of the urban transportation network.

In this paper, two cities were selected as comparison cases: Atlanta, Georgia, and Austin, Texas. These cities were selected since the cities needed to have a JUMP bicycle program operating in the city, as well as a bike share system that did not include electric bikes. A secondary benefit of the selection of these two cities is the research team's familiarity with each city – most notably so for Atlanta. Although a number of studies have already been conducted on the topic of electric bikes around the world, few studies have been conducted where e-bikes were observed as a natural part of a city's infrastructure. The objective of this paper is therefore to investigate the impact that e-bikes are having at a broader level on each of the two cities through the use of bikeshare data from organizations that run fleets of electric and non-motorized bicycles.

CHAPTER 2. LITERATURE REVIEW

In order to understand what the impact of e-bikes has been in other locations, a review of the current literature on e-bikes was completed. Many of the sources cited surveys, primarily online, as their method of research and several conducted trials with small sample sizes.

2.1 Characteristics of e-bike use

In order to better understand what impact on cycle commuting the e-bike may have, it is useful to first understand what the more general barriers to bicycle commuting are. In a 2017 survey in Norway, researchers presented the question of what the greatest barriers to cycling were to local residents. The 5,462 respondents were asked to choose their three top barriers from the ten potential barriers. The five barriers most selected are presented below:

1. Not good enough infrastructure (46%)
2. Feels unsafe (40%)
3. Weather concern (34%)
4. Too physically demanding (22%)
5. Steep hills (18%)

These five barriers were selected more often than the other five barriers: Need to bring children or goods; Need a car for work; Fearful of sweating / no shower at work; No bike parking; and in poor health. Of the top five barriers, two of them are directly mitigated by the introduction of an e-bike and a third barrier, “feels unsafe”, is partially mitigated – as the study suggests users feel safer on an e-bike due to the increased potential speed allowing bikers to keep up with traffic (7). After participating in the initial survey, 220 participants were given a chance to ride an e-bike. Of the participants, 77% cycled more than before once receiving the e-bike and 56% said the bike allowed them to take trips not taken before. Figure 1 indicates the ways participants had taken advantage of the extra power from the motor. The study found that these same respondents had an increase of 27% in the price they were willing to spend on an e-bike after being exposed to one. (7)

Figure 1: How Participants had taken advantage of the electric motor (7)

In a similar survey in Norway, 910 respondents, 252 of whom own electric bikes were surveyed. Again, in this study, many of the barriers removed by e-bikes were the same, most notably that longer trips can be taken with less physical effort. This reduction in the physical effort can also benefit individuals with some form of physical limitations (27). Interestingly, those who stated their primary barriers were related to usability and safety had a decrease in the likelihood of choosing an electric bike, while those whose primary barriers were related to environments and other actors had a positive indication on the decision to buy an e-bike. This further accentuates the point that the topography and distance-based barriers are the barriers most likely to be overcome by electric bikes as a transportation option (27). One study in Gothenburg, Sweden found that e-bikes could theoretically remove barriers expressed by 53% of respondents to a survey for bicycle commuting and 76% of respondent's barriers could be overcome by an E-Bike pool or share. Figure 2 illustrates the barriers for members of the community and how they are mitigated by e-bikes. These results indicate that there is a large potential for e-bikes to open the transportation mode and attract more individuals (3).

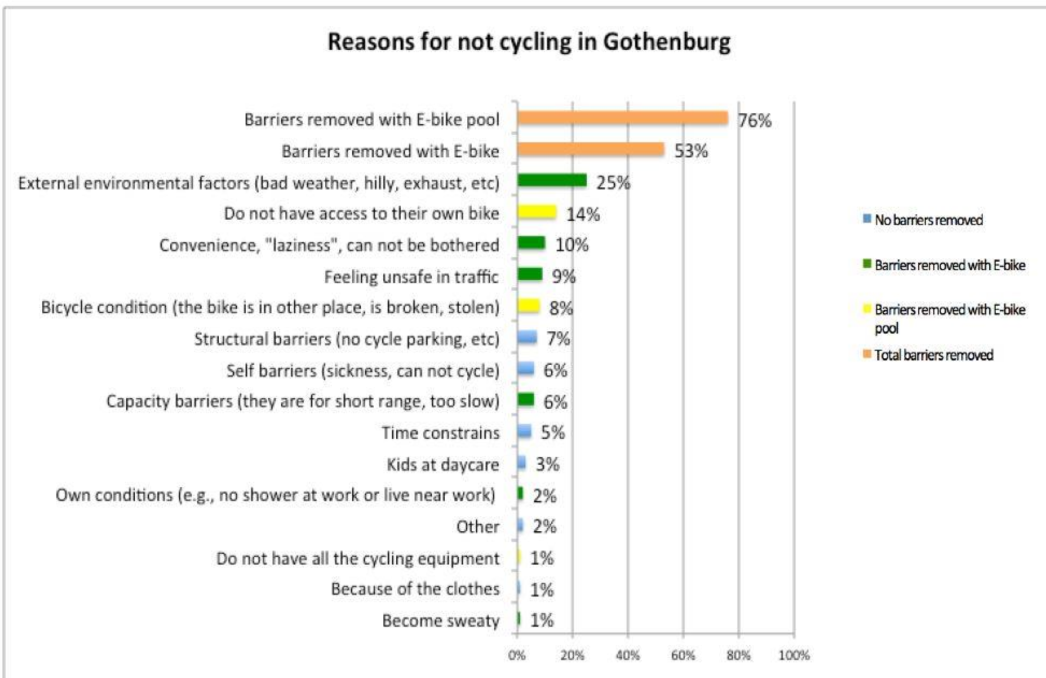

Figure 2: Reasons for not Cycling (3)

Building on this information and bringing the study area closer to the location of the current study, the 2018 North American Survey of Electric Bicycle Owners asked respondents from all over the country a similar question. In this case, all respondents were already e-bike riders. Figure 3 illustrates the results of this portion of the study. The riders were asked what main barriers were overcome as a part of the switch to e-bike riding and found similar results to the studies from Norway (17). According to the literature, distance-based, topography-based and physical exertion-based barriers are the main barriers able to be overcome by an electric bike and are a large part of the reasons for making a switch to e-bike commuting (12)(25)(5)(27)(10)(15).

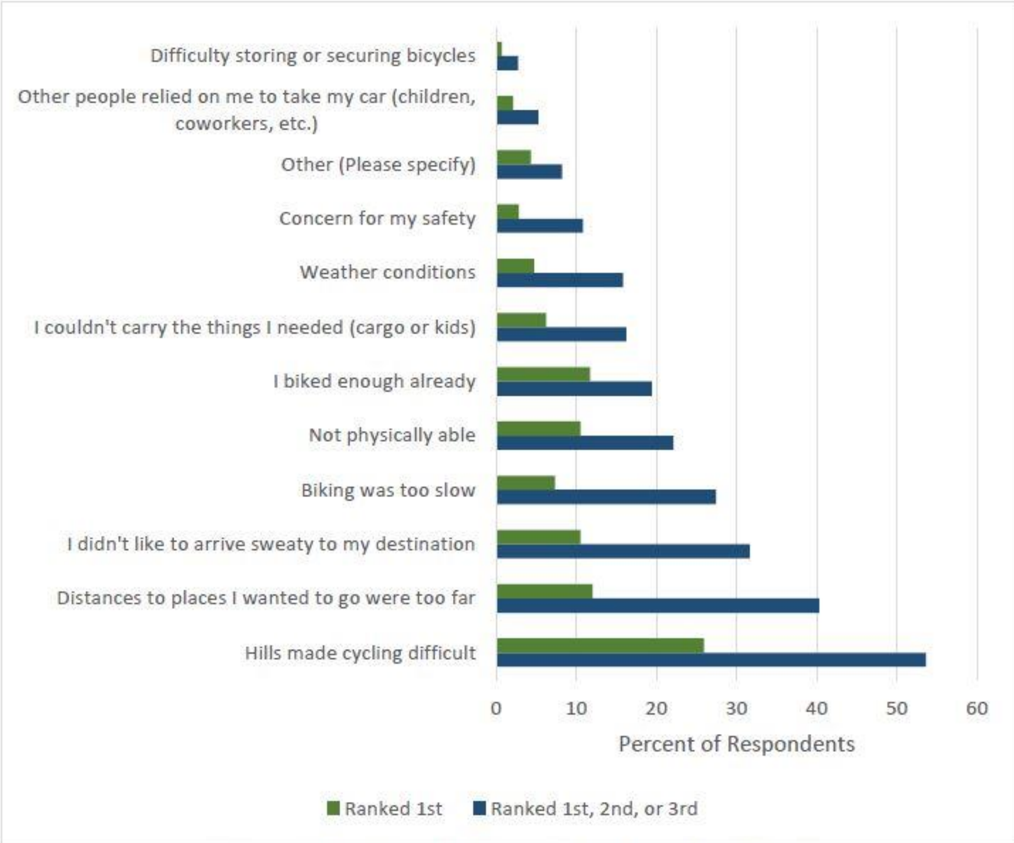

Figure 3: Important Barriers to Riding a Standard Bicycle (17)

2.2 Electric Bicycle Trials

Additional literature has explored trials, where users were introduced to the e-bike either as a bikeshare option for the first time or as a part of a specific study trial. The first e-bike share in the United States was introduced in 2011 at the University of Tennessee, Knoxville. The system contained both regular bikes as well as the e-bikes. There was a total of 93 users enrolled in the program in the first year. The study found that 22% of users were responsible for 81% of the trips taken in the system. Follow up surveys found that class-related purposes accounted for 40% of all trips and the purpose of the bike's trips was more diverse with e-bikes (12).

Another study was completed with families in the San Francisco Bay area to understand the potential for an electric bike to replace a minivan. The study found that the e-bike serves as a viable replacement for the minivan for purposes of transporting young children and cargo. The additional weight of children and cargo accentuates the benefit of an e-bike over a standard cargo bike (28). The price to purchase a cargo e-bike was found to be the largest barrier that must be overcome to promote this mode choice (28). Another trial from Brighton in the United Kingdom consisted of 241 individuals that were given an electric bike for a six to eight-week trial. Over the course of the trial, 43% of participants indicated they drove cars less and the proportion of respondents saying they would bike to work at least one day a week increased from 29% to 73% if the electric bike was available (1). A similar study was performed in the city of Groningen, Netherlands with 24 individuals who owned their own e-bike. Through the course of the study it was found that of 34.5% of trips made by the participants in the study were made on their e-bike. The following table shows in greater detail the purposes of the trips from the study period (25).

Table 1: Frequencies of trips by mode and purpose (25)

Purpose	Car	E-bike	Walk	Bike	Bus	Train	Other	Total *(%)*
Work	80	134	15	1	13	5	2	250 *(22.9%)*
Personal	6	8	0	0	0	0	0	14 *(1.3%)*
Free time	81	24	15	5	1	3	0	128 *(11.7%)*
Convenience shop	51	12	14	17	1	0	0	95 *(8.7%)*
Goods shopping	20	5	1	5	0	1	0	32 *(2.9%)*
Appointment	4	6	0	0	0	0	0	10 *(0.9%)*
Visit	65	10	6	2	1	1	2	87 *(8.0%)*
School	21	29	1	7	0	0	0	58 *(5.3%)*
Home	190	148	33	29	9	5	2	416 *(38.2%)*
Total (%)	518 (47.5%)	376 (34.5%)	85 (7.8%)	66 (6.0%)	25 (2.3%)	14 (1.3%)	6 (0.6%)	1090 *(100%)*

Reviewing the trials, it is evident that the introduction of an electric bicycle in the controlled environments of a trial has shown a drastic increase in the proclivity to utilize an electric bicycle as a transportation option (12)(28)(1).

2.3 Relevance of E-Bikes

The previous two sections of the literature review focused on the individual e-bike riders themselves, including the change in trip types and trip lengths, as well as the number of trips taken in a given time period. For this to be meaningful, it needs to be known if the new e-bike trips are being generated as new trips altogether, are cannibalizing other modes of low-impact transit such as the regular biking or walking or are actually working to be a substitute to cars. A survey of 27 electric bike riders in the Sacramento area found that 80% of previous car owners reported driving “a lot less” or “a little less” during the trial period with an electric bicycle (26).

A study using a survey of 40,000 Dutch citizens found that the use of an electric bike drastically reduced the number of trips that were taken on a conventional bike. However, when the electric bike was used it caused a reduction in the number of trips taken by car or public transportation. The study did note that the reduction in the number of vehicle trips is much greater for an electric bicycle than a conventional bicycle. In addition, the study found that car owners were much more likely to substitute their own vehicle trips with an electric bicycle than a conventional bicycle. The author notes that one reason this study is important is that it focuses on the general population rather than a survey of exclusively e-bike users (11). In a trial in Portland, Oregon, 106 participants were given an e-bike to ride for 10 weeks. In addition to detailed before and after trip information, cyclists indicated that they had gained confidence in cycling as a part of the exposure to an electric bicycle (19). The study showed that among cyclists in the study, there was a drastic increase in bicycle trips for all purposes while the e-bike was available, with personal errands showing the largest increase; These increases are illustrated in more detail in Figure 4 below (19).

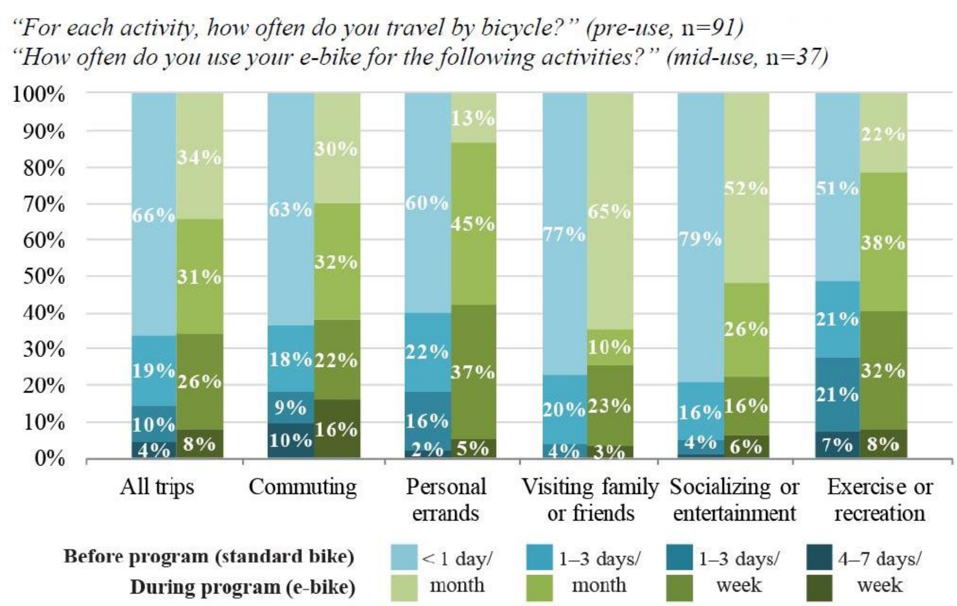

Figure 4: Frequency of bicycle use by trip purpose, before and during program (19)

A study of 427 e-bike users in Denmark found that, while conventional bikes were the mode most often replaced by an e-bike, cars were the second most common trip that was replaced – followed by the bus, then walking, and then the train/metro. In addition, of the three categories of e-bike users in the study (enthusiastic, utilitarian and recreational), 50% of enthusiastic e-bike users stated they had bought an e-bike to replace a car, along with 32% of utilitarian bikers and 23% of recreational bikers. Table 2 shows the agreement of different types of e-bike riders to the replacement of another mode by c-bike. The higher means (M) indicate that riders are more likely to substitute trips from that mode. This increase indicates that there are real auto trips being replaced by the e-bike in Denmark (10).

Table 2: Agreement to use of e-bike as a replacement of trips by other modes (10)

Replaced mode	Cluster	*M*	*SD*	ANOVA
Conventional bike	Enthusiastic e-biker	3.86	1.28	$F(2,416) = 11.49^{***}$
	Utilitarian e-biker	3.09	1.43	
	Recreational e-biker	3.42	1.48	
Walking	Enthusiastic e-biker	3.07	1.38	$F(2,419) = 8.63^{***}$
	Utilitarian e-biker	2.39	1.35	
	Recreational e-biker	2.69	1.44	
Bus	Enthusiastic e-biker	3.47	1.42	$F(2,414) = 20.49^{***}$
	Utilitarian e-biker	2.81	1.52	
	Recreational e-biker	2.40	1.51	
Train/metro	Enthusiastic e-biker	2.71	1.49	$F(2,397) = 12.74^{***}$
	Utilitarian e-biker	2.17	1.36	
	Recreational e-biker	1.90	1.27	
Car	Enthusiastic e-biker	3.58	1.18	$F(2,402) = 9.44^{***}$
	Utilitarian e-biker	2.89	1.46	
	Recreational e-biker	3.18	1.41	

$^{***}p < .001$.

In Nanjing China, 403 survey respondents were asked what mode they would take if they were not using an e-bike, Figure 5 shows the results, most notably, walking is the 4th most common mode, behind the private car (15).

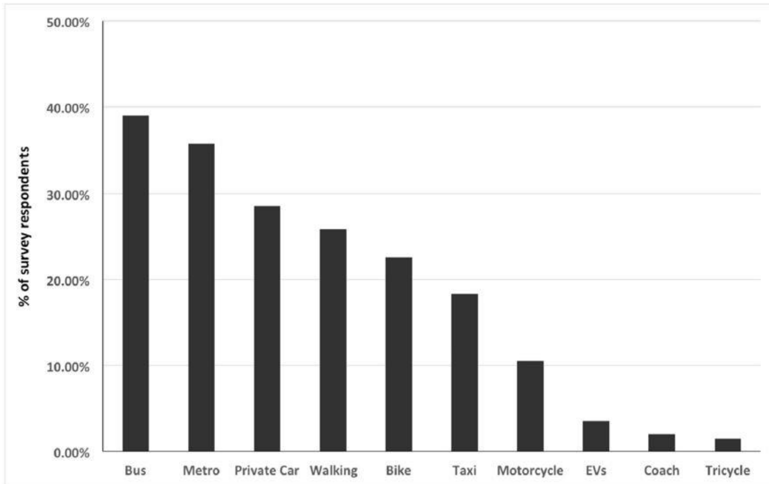

Figure 5: Alternative Mode Choices in the Absence of e-bikes (15)

Two other studies in China found that when looking at individual household factors in an intended purchase model, the ownership of an e-bike had a positive correlation with the intent to buy a car. This indicates that e-bikes may not be having the impact of making the purchase of a car less likely – rather this study found that demographic factors, such as income, had the greatest impact on the likelihood of purchase of a car. This may indicate that the ownership of an e-bike was more of a proxy for income than an independent variable itself (16). A study in Nanjing, China found that users tend to make a shift towards the most convenient mode to take, rather than e-bike specifically. The study, therefore, argues that e-bike users may one day revert to car travel if it becomes more convenient (14).

A study of an incentive program in North Brabant, Netherlands studied the decrease in regular bicycle and car usage as a result of the implementation of the incentive program, which provided a monetary incentive of a few cents per kilometer cycled on the e-bike.

Prior to the introduction of the incentive program, 62% of commute trips in North Brabant were made by car and 33% by bike. In the first month of the program, transportation usage dramatically shifted to 25% car trips, 1% regular bike trips and 68% e-bike trips. (4)

An additional study of North American e-bike commuters found that 65% of e-bike owners purchased the e-bike to replace some car trips, and when asked how often they rode a nonmotorized bicycle prior to the purchase of an electric bike, 55% responded they rode daily or weekly, with 45% riding a bike less than once per week. After the purchase of an e-bike, 95% of respondents said they rode daily or weekly (24). For a study of a Norwegian population, 66 participants were randomly selected and given e-bikes for a trial. E-bikes increased the bicycling for commuting and leisure significantly in the form of the number of trips as well as distance traveled. The increase in the number of trips was from 0.9 to 1.4/day and the distance more than doubled from 4.8 km to 10.3 km. When looking at where these trips came from, the share of trips taken on an e-bike rose from 28% to 48% (6).

In general, the literature would suggest that, while e-bikes tend to cannibalize some trips from the more benign modes of traveling, there is certainly a reduction in the number of car trips taken as a result of the introduction of e-bikes in some form. Therefore, e-bikes clearly have the potential for encouraging alternative modes of transportation. The work being described in this paper adds to the research in a meaningful way by observing the impact that an organic introduction of e-bikes can have on the existing bicycle infrastructure.

2.4 Expansion of E-Bike Impact

This final section of the literature review investigates the impact that the exposure to electric bicycles can have on future e-bike use and general mode shift towards the use of bicycles for trips of multiple purposes. A study in Waterloo, Canada focused primary on senior citizens and attempted to understand the potential of e-bikes to open bicycling back up to a large part of the population. Figure 6 shows the re-uptake of bicycling as a mode of transportation after the introduction of an electric bicycle. The study of 37 elderly individuals found four factors that influenced increased bicycle usage amongst the study group: increased convenience, reduced physical exertion, reduced reliance on a vehicle, and fun. (13)

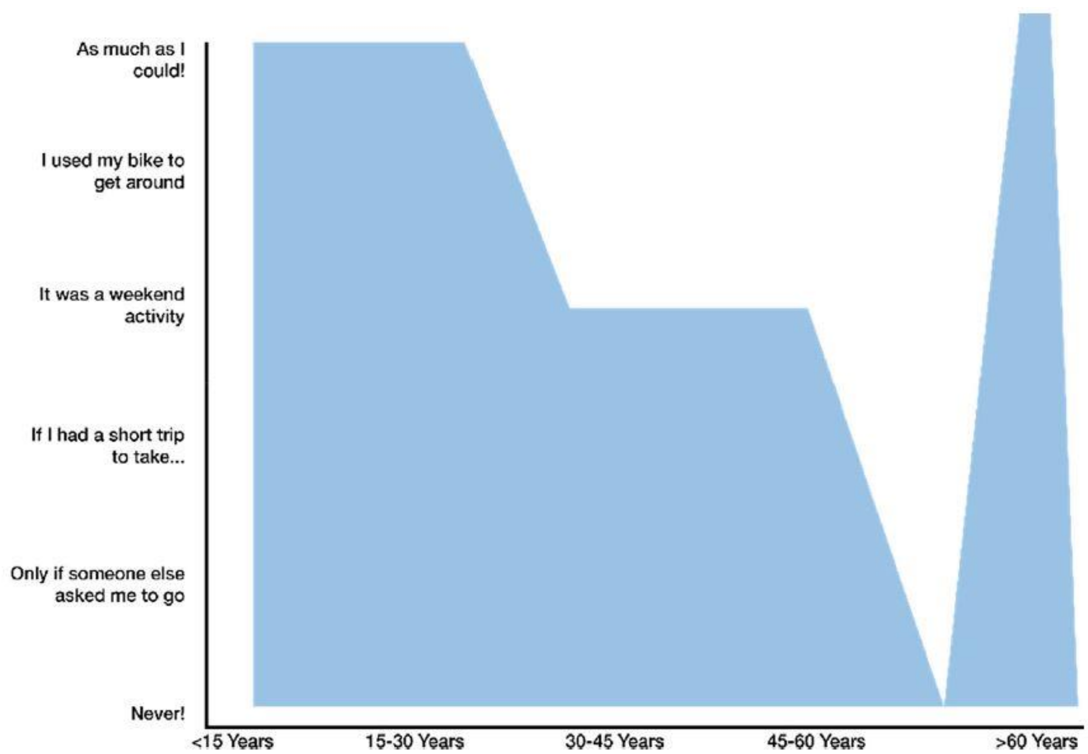

Figure 6: Cycling History of Participant with Injury at age 60 who returned to cycling using and e-bike (13)

A study in Zurich, Switzerland found that the primary distance of the trip for which the e-bike was utilized was 2 kilometers (1.2 miles). As shown in figure 7 this trip distance is comparable to the trips taken by a bus, tram or regular bicycle. The figure also indicates that the electric bike does not have a longer average distance than a regular bicycle. Through the analysis of rental start locations and the time of day of booking, this study did find, however, that a major share of the demand on the e-bike system was for commuting trips. (8)

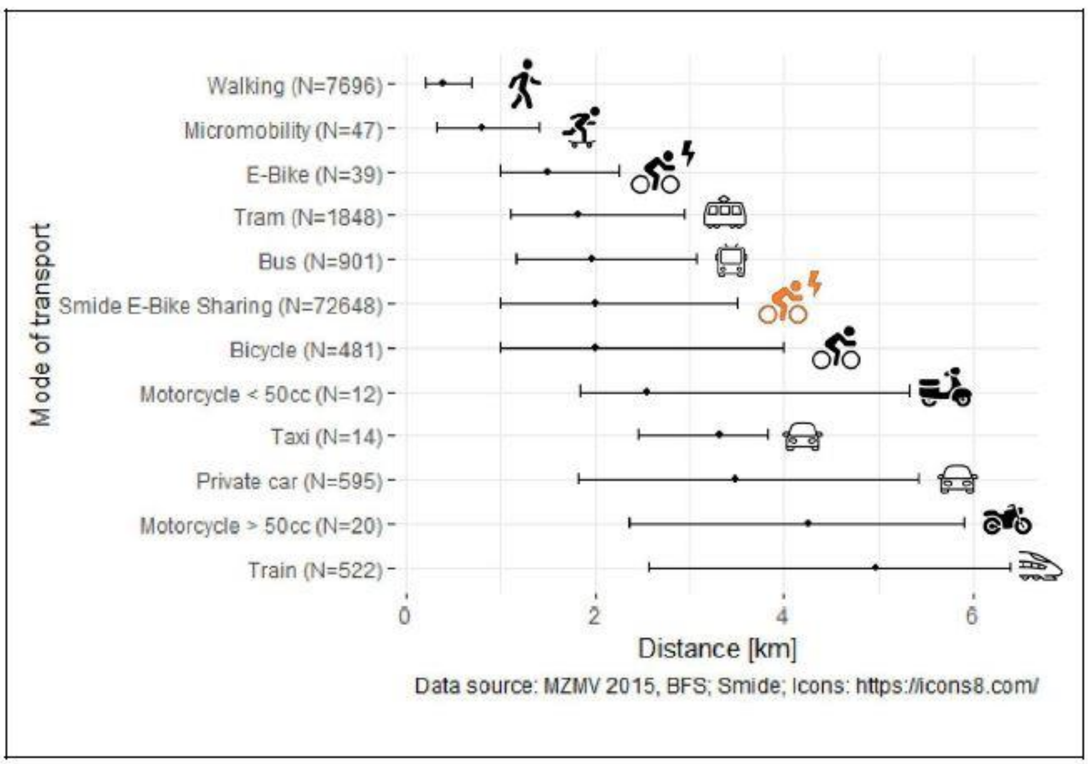

Figure 5. Distance ranges in the urban passenger transportation market: median, and the upper/lower quartiles.

Figure 7: Distance Ranges in the Urban Passenger Transportation Market: Median, and the upper/lower quartiles (8)

A study of several incentive programs around the county found that lowering the cost of entry into the e-bike commuting routine was one of the best ways to encourage new riders. These incentives took several forms, from tax subsidies to employer e-bike rental. The incentive program investigated in Burlington Vermont found that after 106 participants were given an electric bicycle for 1 week 17% purchased an electric bicycle in the next 6-12 months (21). An additional study of an incentive program in Switzerland where participants were given an electric bicycle for 2 weeks in exchange for their car keys found that 15% of the 1800 participants purchased an electric bike within 1 year of the study (23) (21). A follow up study from this trial yielded a sustained shift in preference away from cars and towards the electric bicycle. Figure 8 indicates the shift in habitual association of the paired comparison test during the follow up study. (22)

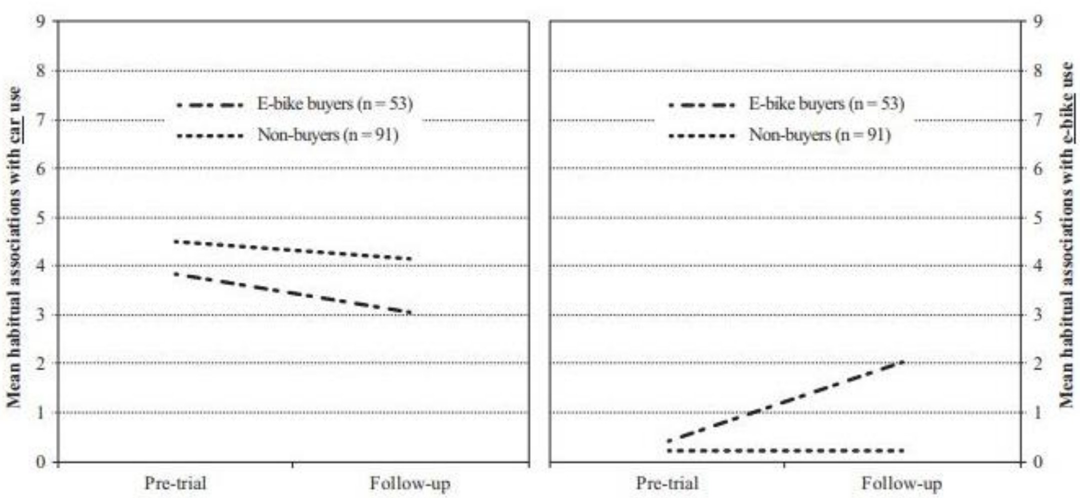

Figure 8: Change in habitual associations with car use and e-bike use over time for buyers and non-buyers of e-bikes. Main effects of time and purchase behavior and their interaction on habitual associations with car use (left side) and e-bike use (right side; N= 144) (22)

This continues to build the case that the mere introduction of users to the electric bicycle increases the likelihood that users will make a shift towards commuting via electric bicycle in the future. Bikeshares using electric bicycles present a unique opportunity to expose a large portion of the general populations of cities to the transportation mode and research suggest that this introduction may have some longevity.

CHAPTER 3. METHODOLOGY

The study area for this project is comprised of the downtown area of the city of Austin, TX, and Atlanta, GA. While these systems do have some operational differences such as docking requirements, pricing structures, and system areas, the systems provide a comparison of a bikeshare comprised of solely non-motorized bicycles to a bikeshare comprised of only e-bikes.

3.1 System Overviews

3.1.1 Relay Bike Share Data

Relay Bike Share opened in 2016 as the non-motorized bicycle share program in the city of Atlanta. The system has a bounded system area and functions as a semi-dockless bike share system within this area. There are stations where the bikes may be returned, however, a bike can be dropped anywhere within the system area for a $2 fee. There is a $1 incentive to later return these bikes to the hub locations. Trip data for the Relay system in Atlanta is publicly available. This data contains a large amount of information concerning the demographics of the users, and other system status checks, however for the purposes of this project, only the starting and ending latitude and longitude coordinate fields were utilized. Since the other two systems did not provide distances/durations, the trip distances and durations were obtained utilizing the google maps bicycling directions API to allow for consistency in the comparison.

3.1.2 Austin B-Cycle Data

The city of Austin's B-Cycle program began in December 2013. It is similar to the Relay system; however, these bikes are a part of a strictly hub-based (dock) bikeshare system. The bikes must be checked out and dropped off at one of the many hub locations around the city. The B-Cycle system publishes data online which it updates monthly containing the trip information for the system. Because the system is hub-based rather than dockless, the trip data contains only the starting and ending hub locations and ID numbers. In order to bring the data into the same format, the latitude/longitude was added for each of the hub locations then trip distances and durations were obtained utilizing the google maps bicycling directions API to allow for consistency in the comparison.

3.1.3 JUMP Bikes GBSF

JUMP is a company which operates dockless e-bikes and e-scooters in several cities around the country - two of them being Atlanta and Austin. The company does not share the trip data of the operating systems publicly, however, through the General Bikeshare Feed Specification (GBFS) the real-time locations of the bikes available for rent are available online as a json file. In order to extrapolate trips from the real-time available bike locations, the data was accessed every 15 minutes, and the most recent set of data was compared to data collected in 15-minute increments going back 2 hours. If the same bike ID changed GPS coordinates during these time intervals, the change was collected as a trip. The trip data was then processed to remove double inputs of trips which occurred due to the collection method by removing trips with the same bike ID and starting/ending lat/lon coordinates. One major difference between this data and the data from the other systems is that the duration/trip distance must be extrapolated, meaning that if a trip started and ended in the same location, the trip distance would be under 50 meters and would not be counted. This difference was accounted for by utilizing the same methodology to calculate the distance for each of the other systems and removing the trips measuring less than 50 meters.

3.2 Process and Metrics

In order to gauge the differences between the sets of bikeshare trip data, the following process and set of metrics is applied to each dataset.

Step 1. Bring the data from the various systems into a consistent format for analysis. The data from the three systems (JUMP, Relay and B-Cycle) comes in several different formats. The first step is to organize the data to ensure that all the data sets contain the starting/ending latitude and longitude as well as the time the trip began.

Step 2: Addition of consistently formatted trip distance and duration: The Google Maps biking directions API was utilized to generate trip distances and durations for all the datasets. Due to the fact some systems reported trip distances and others did not, in the interest of a robust comparison the same methodology was utilized to obtain the trip distance and duration.

Step 3: Calculate the Trip Counts, Average Trip Distance, and generate the trip distance histograms. The R function GGPLOT was utilized to generate the histograms presented in this thesis.

Step 4: Utilize a Geofence to flag any trip that begins or ends within the designated central business district of each city. The percentage of the total number of trips for each system in each city was then calculated.

Step 5: Create a heatmap of the origins and destinations utilizing the leaflet function in R within the cities analyzed. These maps indicated a large student population utilizing the bikeshare system, which prompted the inclusion of the pass type for the Relay Bike Share and the Austin B-cycle system. The figures presented in this thesis were tabulated from the data available from the Austin B-Cycle system and Atlanta Relay System.

Step 6: Create Route Path Heatmaps of the trips made on each bike-share system to get a sense of how the users move about the cities. These heat maps were created by utilizing the Bing Maps API function to fetch the walking directions for each set of coordinates. These walking directions were then taken and mapped over a base map for each city utilizing the leaflet function in R.

CHAPTER 4. RESULTS

For each of the cities, the number of trips for each month of the study period were recorded. Figure 6 shows these trip details for each month of the study period, compared to the same month of the prior year (2018)

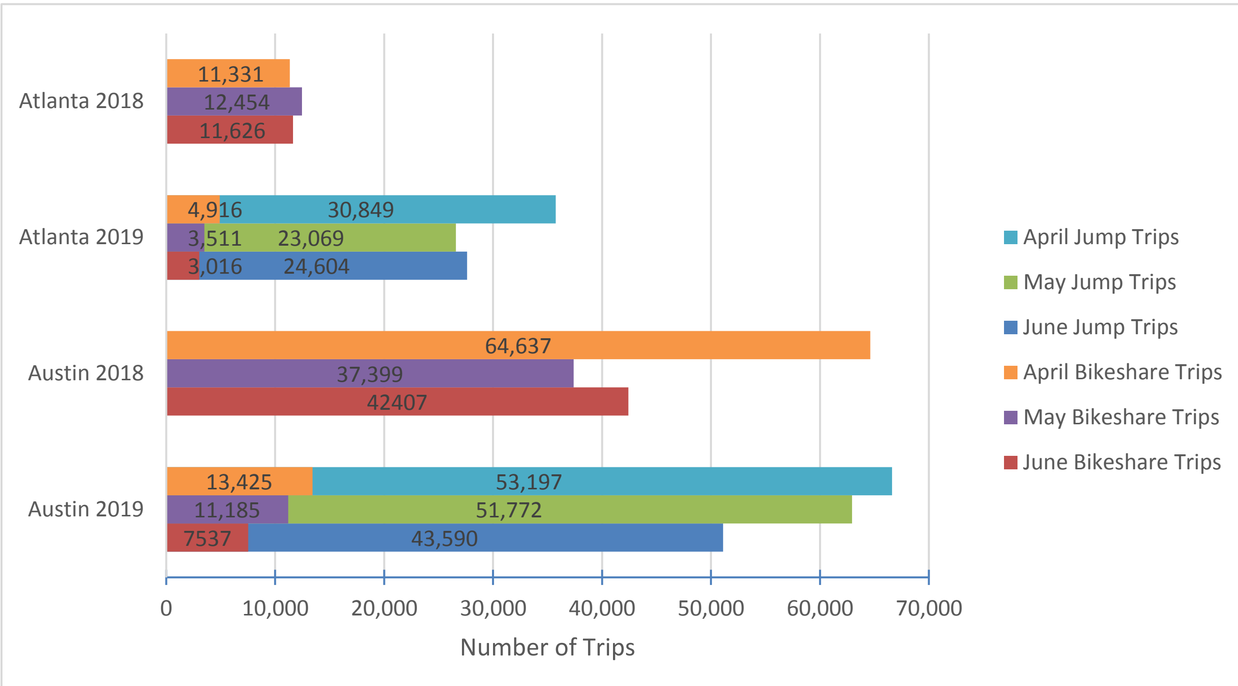

Figure 9: Comparison of Number of Bike Share Trips Taken 2018 Vs. 2019

The data illustrates that there is a substantial reduction in the number of Relay trips from 2018 to 2019 but that this reduction is more than made up by the new Jump trips, showing an overall increase in trips. In the three months combined, there is roughly seven times the number of trips on Jump as on Relay Bike Share. When examining Austin, Texas, similar trends are observed. The cannibalization of Austin B-Cycle Trips is more severe than in Atlanta but there is still an increase in the overall number of trips.

Table 3 shows the percentage of the trips beginning or ending in the CBD. The number of trips which involved either origins or destinations located within the CBD greatly increased with the introduction of JUMP bikes in Atlanta and observed a milder increase in the city of Austin.

Table 3: Percentage of Trips Beginning or Ending the in CBD

Month	Atlanta		Austin	
	Relay	JUMP	B-Cycle	JUMP
April	11%	18%	18%	24%
May	11%	20%	23%	26%
June	2%	22%	26%	26%
Total	8%	20%	22%	26%

Average trips distance remained constant between the two bikeshares in Atlanta with an average of 2,153 meters for JUMP and 2,113 meters for Relay. In Austin the average trip distances were greater at 2,328 meters for JUMP and 1,739 meters for B-Cycle. Figures 7-9 illustrates similar trip length distribution between Relay/JUMP and B-Cycle/JUMP during the months of this study. This finding is compelling, given that the literature reviewed would have suggested that the trips would have averaged longer with the introduction of the hub motor.

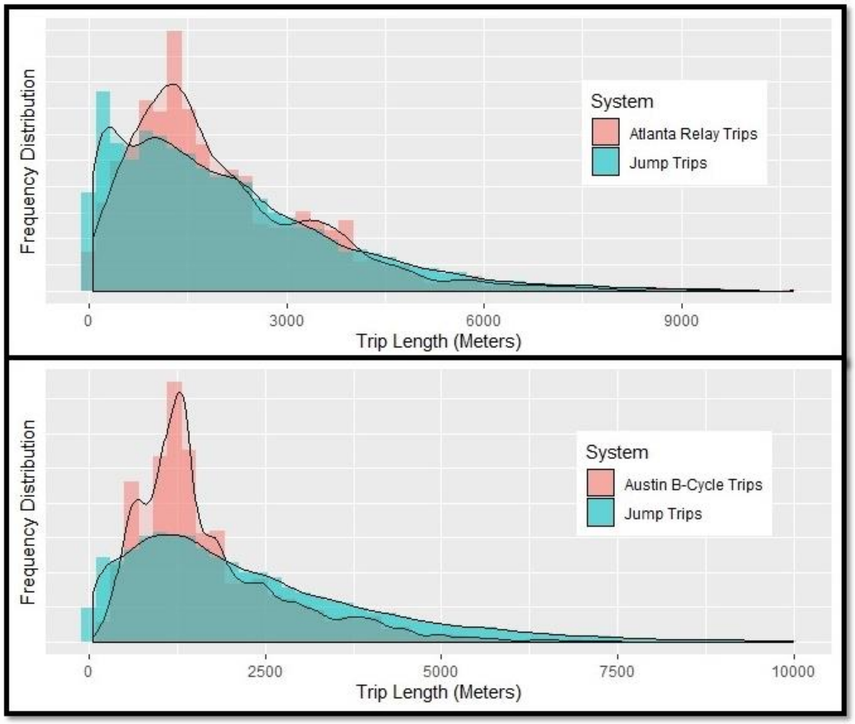

Figure 10: April Trip Lengths Histograms (Atlanta Top, Austin Bottom)

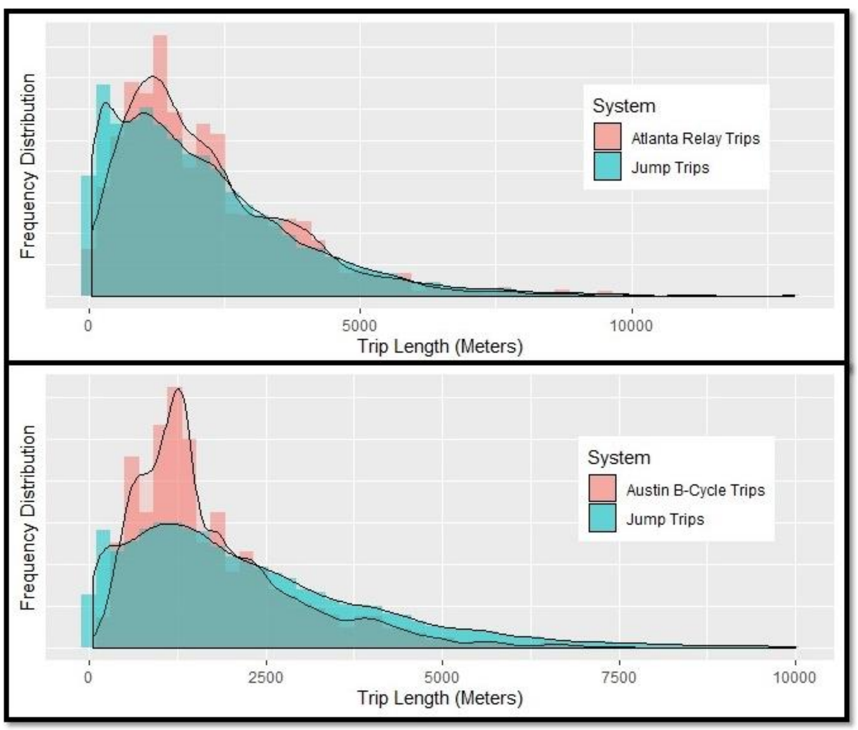

Figure 11: May Trip Lengths Histograms (Atlanta Top, Austin Bottom)

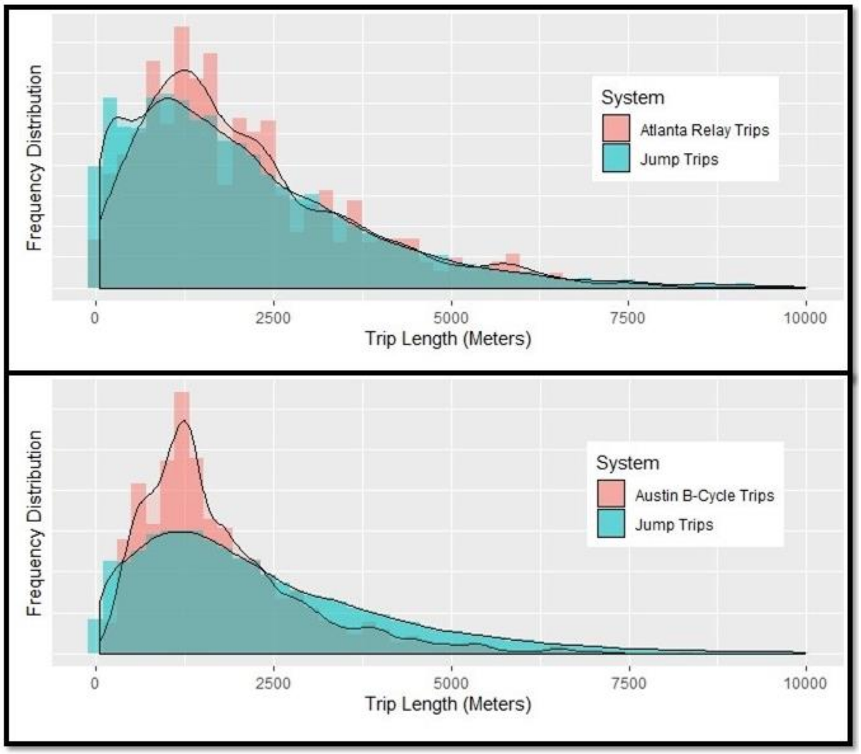

Figure 12: June Trip Lengths Histograms (Atlanta Top, Austin Bottom)

A more pronounced difference in the two systems begins to emerge in Figures 10-12. The geographic distribution of the JUMP bicycles seen in Atlanta is much larger than that of the Relay system. The hot spots on each heat map illustrate that the Relay system is hottest over Piedmont Park in Atlanta, and the JUMP heatmap is hottest over the Midtown business district and the Beltline corridor, which is a mixed-use trail connecting Piedmont park to several other neighborhoods. This finding is further reinforced by the findings in Table 3. The JUMP bike heatmap also expands further north than that of the Relay bicycles. This indicates that even though the individual bike trips may be similar in length, the geographic reach of the JUMP system is much greater than that of the Relay bikes in Atlanta.

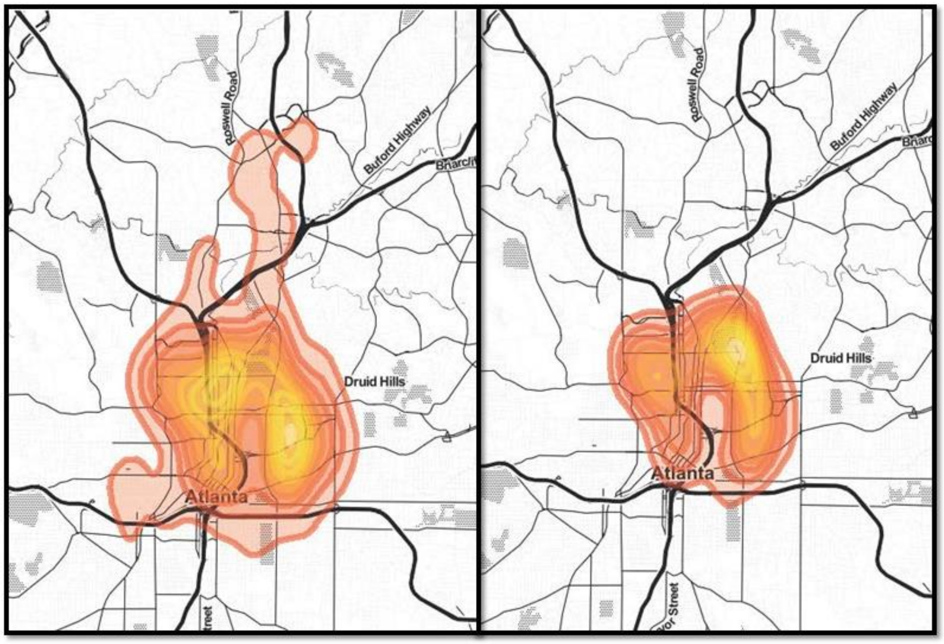

Figure 13: Atlanta, GA April 2019 Heatmaps (JUMP Left, Relay Bike Share Right).

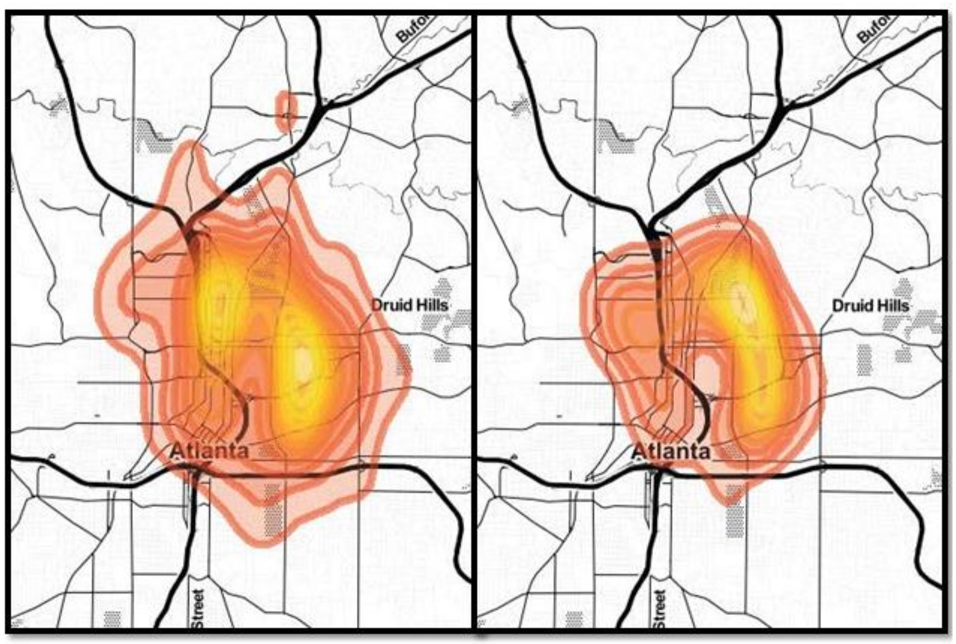

Figure 14: Atlanta, GA May 2019 Heatmaps (JUMP Left, Relay Bike Share Right).

Figure 15: Atlanta, GA June 2019 Heatmaps (JUMP Left, Relay Bike Share Right).

A similar trend is observed for Austin, Texas. Figures 13-15 shows the heatmaps for both the JUMP system and the B-Cycle system. The coverage area is larger on the JUMP system. The central hot spot for bicycle usage shifts from the University of Texas for B-Cycle usage to the central business district for JUMP usage. This indicates that there may be a very large student population utilizing the B-Cycle system. An analysis of the B-Cycle membership types shows that around 40% of the trips were completed by University of Texas students during the 2019 study period.

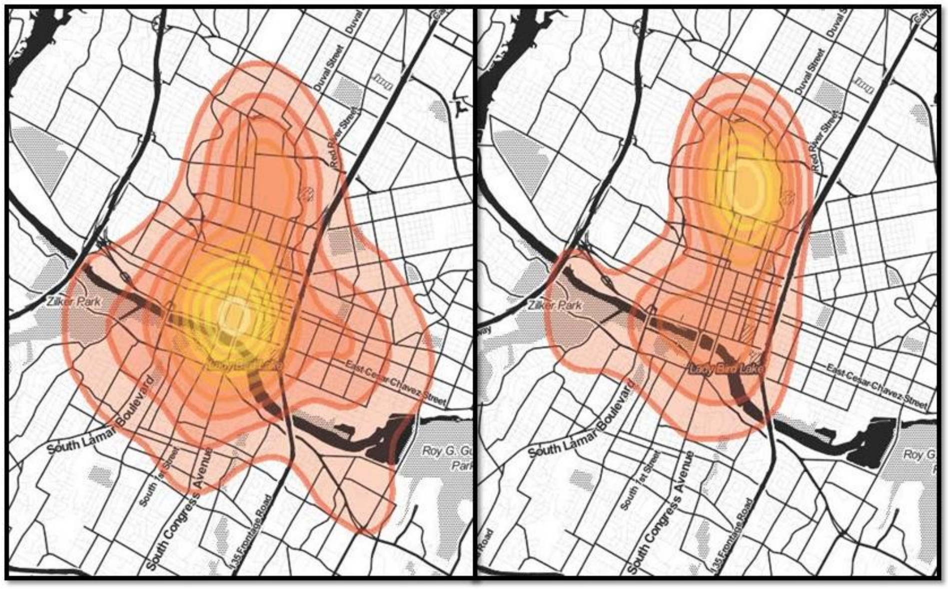

Figure 16: Austin, TX April 2019 Heatmaps (JUMP Left, Austin B-Cycle Right).

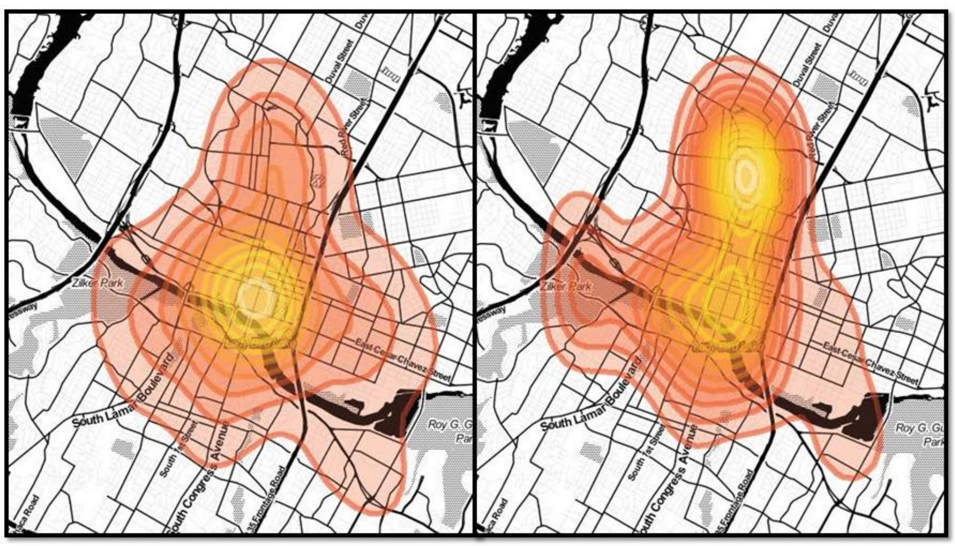

Figure 17: Austin, TX May 2019 Heatmaps (JUMP Left, Austin B-Cycle Right).

Figure 18: Austin, TX June 2019 Heatmaps (JUMP Left, Austin B-Cycle Right).

To further explore the differences in user groups, the transaction types for both the Austin B-Cycle system and Relay Bike Share system were explored for both 2018 and 2019 for the study months of April, May, and June. Table 4 shows the membership types for the Relay system. The largest user group for both time periods were the “Pay as You Go” transactions – these made up 56% of the trips in 2018 and 44% of trips in 2019. There are fewer transactions of all transaction types as a result of the introduction of the JUMP bike system, however as a percentage of trips, the “Pay as You Go” transactions are the largest group that has been impacted by the introduction of the JUMP system. This indicates that the casual users are making a shift towards the JUMP bike system at a faster rate that the users of the system under the other membership types.

Table 4: Transaction Types for Relay during 2018 and 2019 Study Period

	April		May		June		Total			
Relay Pass Type	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Annual Pass	764	601	773	420	819	259	2,356	1,280	7%	12%
Monthly Pass	1,191	505	1,456	521	1,484	521	4,131	1,547	12%	14%
Walk Up	5,985	2,050	7,162	1,530	6,753	1,256	19,900	4,836	56%	44%
SNAP Pass Subscription	429	174	399	102	395	83	1,223	359	3%	3%
Student Pass Subscription	1,843	927	1,674	710	1,485	726	5,002	2,363	14%	21%
Other	560	256	592	228	511	168	1,663	652	5%	6%

The Austin B-Cycle system has seen a much greater reduction in the number of trips than Relay Bike Share when comparing the time period pre and posts the introduction of JUMP bikes. As mentioned previously, the University of Texas students are the largest users of the system, both in 2018 and 2019. This group saw the most significant decline in the number of transactions as well. Interestingly, for the Austin B-Cycle system, the "Walk Up" users ("Walk Up" functions similarly to the "Pay as you Go" users in Atlanta) saw the largest increase in the percentage of trip transaction types for the system – even though from 2018 to 2019, the reduction in transaction numbers was quite drastic.

Table 5: Transaction Types for Austin B-Cycle during 2018 and 2019 Study Period

	April		May		June		Total			
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Annual Pass	4,434	1,620	4,181	1,664	4,562	1,407	13,177	4,691	9%	19%
Explorer	1,029	366	816	558	833	235	2,678	1,159	2%	5%
Monthly Pass	1,620	355	1,163	490	1,283	551	4,066	1,396	3%	6%
U.T. Student Membe	44,641	5,962	20,918	3,919	24,897	2,213	90,456	12,094	63%	49%
Walk Up	10,758	3,955	8,340	3,552	8,740	2,675	27,838	10,182	19%	41%
Weekend Pass	2,151	888	1,949	914	2,053	453	6,153	2,255	4%	9%
Other	4	279	32	88	33	3	69	370	0%	2%

Due to the nature of the JUMP bike system, all trips would function effectively as "Pay as you Go" or "Walk Up" – as users simply need to download the Uber or JUMP app to have access to the JUMP bike system and there are currently no multi-trip pass options.

The final piece of analysis is the route path heatmap. Figures 16-18 shows the side by side comparison of the route path heatmaps for the JUMP and Relay systems in the city of Atlanta. This comparison further substantiates the argument that the JUMP bike network is further reaching. The map seems to show that the JUMP bike system provides more flexibility in destination choice. The Relay network has a much more concentrated area with fewer number of routes taken between the different destinations, while the JUMP system shows destinations over a much larger area – indicating that more of the city is much more accessible to bicyclists with the introduction of the motor.

Figure 19: Atlanta, GA April 2019 Route Path Heatmap (JUMP Left, Relay Right)

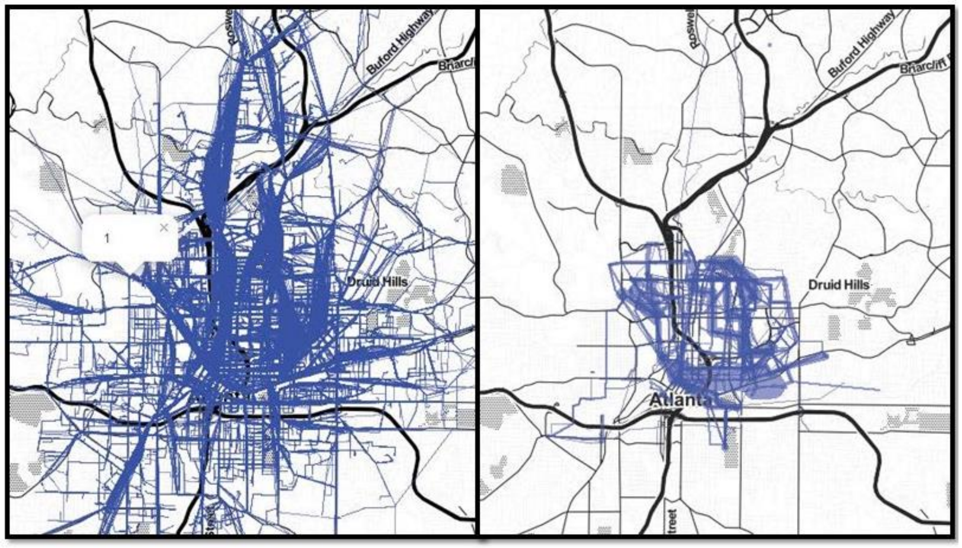

Figure 20: Atlanta, GA May 2019 Route Path Heatmap (JUMP Left, Relay Right)

Figure 21: Atlanta, GA June 2019 Route Path Heatmap (JUMP Left, Relay Right)

The route path heatmaps in the city of Austin shown in figures 19-21 yield a similar comparison. The nature of the B-Cycle system as a hub-to-hub network does inherently limit the extent of the region served by the system, however the difference between the two systems is quite stark in geographical reach and flexibility of the choice of origin and destinations.

Figure 22: Austin, TX April 2019 Route Path Heatmap (JUMP Left, B-Cycle Right)

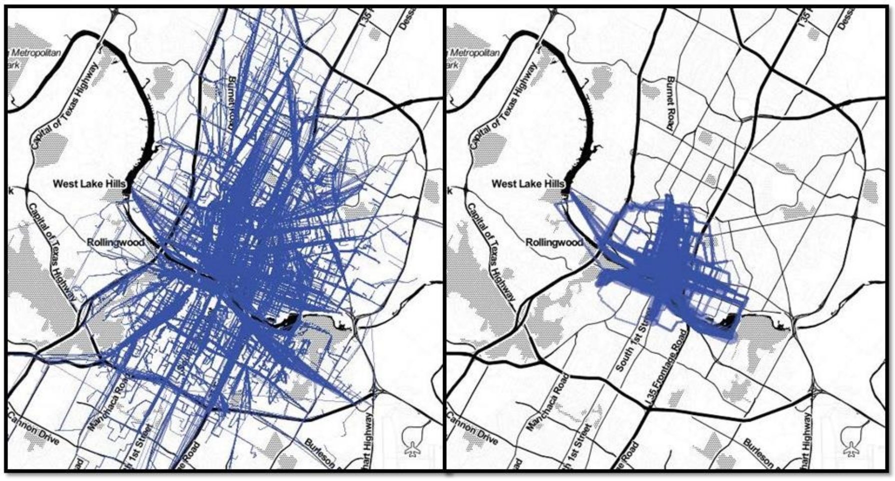

Figure 23: Austin, TX May 2019 Route Path Heatmap (JUMP Left, B-Cycle Right)

Figure 24: Austin, TX June 2019 Route Path Heatmap (JUMP Left, B-Cycle Right)

These route path heatmaps seem to provide insight into the most popular origins and destinations and, subsequently, the paths of least resistance between these pairs. In addition to making the argument that the JUMP bike systems open the cities up to much more mobility via the bicycle, these maps illustrate to city transportation planners where the most common bicycle routes may be. In the route path heatmap of Atlanta, it is clear that several large North/South and East/West bicycle transportation corridors are emerging. A similar evolution can be seen in the city of Austin. These maps provide insights as to where investment in bicycle infrastructure may be the most useful and, conversely, where investment may not be needed. What is made clear by the sum of the results is that through the addition of a motor, the bicycle has been transformed into an extremely viable mode of transportation for both the casual users and commuters in the cities of Austin, Texas, and Atlanta, Georgia. The reach of the networks has expanded greatly, the ease with which the bicycles are able to reach their destinations has increased and the effort level required to get there has been reduced, and the access to e-bikes has become possible for more members of the commuting of both cities.

CHAPTER 5. DISCUSSION

The results of this paper add to the growing amount of research around the topic of e-bikes. The exposure of such a large segment of the population to e-bikes has been shown to have a large impact on the willingness to pay for the service (7). The significance of these findings is further expanded when returning to several of the findings of the literature, such as the pilot electric bike introduction project in Portland, Oregon. This increase in bicycle activity for everyday trips can contribute greatly to the transportation network of cities such as Atlanta and Austin (19).

While this study presented several interesting findings, there are several limitations to the methods presented in this study. The process by which the JUMP bike trip data was collected does not include specific distance or duration information, any information about the individuals completing the trips, or information about the origin/destination; additionally due to the nature of the data, trips which begin and ending In the a similar location were discarded. In future studies more detailed information regarding the route choice and exact distance would eliminate the need to utilize the Google Maps API to obtain this data and provide a more detailed analysis. Efforts by the researcher to reach JUMP and obtain more detailed trip information proved unsuccessful. In addition, this study is comprised of three months of data in two cities – further research including additional cities and multiple years' worth of information would be able to better identify trends and provide a more robust analysis. Additionally, the difference in the nature of the systems may be impacting the increase in the coverage area that was observed. With Relay Bikes, there is a financial incentive to keep the bikes at the docking stations that does not exist in the same manner with the JUMP system. Similarly, the Austin-B-Cycle system is not dockless and therefore the locations where bikes can be obtained and dropped off is limited.

One major factor contributing to the choice to use a bikeshare is how comfortable and convenient the bikeshare is – several studies noted that the degree to which a bikeshare is used is highly dependent on the degree of satisfaction that users have with bike sharing (2)(9). It is therefore vital to ensure that the bikeshare experience is as enjoyable as possible. In addition, individuals who are familiar with the bikeshare were found to be 13.32% more likely to adopt bike sharing as a mode choice (9). The fact that everyday citizens have likely already had an experience with the Uber app would seem to make the use of the same app more appealing because of the familiarity with the existing system. The trip count data points in this direction with the large shift in the pay as you go/walk-up trips moving to the Uber/JUMP platform.

CHAPTER 6. CONCLUSION

When returning to the research questions posed at the beginning of this paper, the evidence from the data analyzed stands in favor of the electric bicycle as a promising addition to the mobility options in the cities of today. The increase in bikeshare usage when utilizing the JUMP bikes with the electric motors indicated that many of the barriers to bicycling have been removed to some extent. In addition, the service area of the JUMP bikeshare system is greatly expanded beyond the service area of the non-electric bicycle share counterparts. The evidence shows that there is cannibalization of the exiting bikeshare trips to make way for the electric bicycle trips, however, the increase in total trips outpaces the cannibalization of existing bikeshare trips. What is clear from all of this is that e-bikes can have a large contribution to the transportation infrastructure of a city. E-bikes go a long way towards mitigating many of the barriers expressed in the literature, however, they are only as effective as the city's transportation infrastructure allows them to be. The route maps shown in figures 4 and 5 show that there are preferred routes through the city and that, even with a motor, cyclists still prefer to ride in protected infrastructure. E-bikes will not solve the issue of cities being built around cars. This research shows the great potential that e-bikes possess to shape the city's transportation network if the mode is effectively incorporated into the city's transportation planning process and meaningfully invested in through infrastructure improvements to make the cities more widely accessible. The positive impacts of wider adoption extend beyond the obvious mobility improvements – e-bikes have also been shown to positively impact the sustainability and CO_2 footprint of the cities in which they operate (20) (14) (28). In the meantime, however, e-bikes will continue to push cities in a positive direction and continue to expose thousands of citizens to the joys of electric bicycling.

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